

## ***Lost Creek, SR 101, MP 174***

### **Regional Geology**

The project area is in the Hoh River valley, on the western flanks of the Olympic Peninsula. The Hoh River is one of the major river valleys originating in the interior of the Olympic Mountains. Bedrock consists of interbedded sandstone and siltstone units that originally deposited in a marginally deep marine environment during the Tertiary (5 to 35 million years ago). These deposits were subsequently tectonically folded and faulted.

The earliest and most extensive glacier occupied the Hoh valley during the mid or late Pleistocene (20,000 to 750,000 years ago). The glacier flowed westward across a landbase that extended beyond the present day coastline. Glacial deposits are found on Mount Hoh, north of the mouth of the river, at an elevation of 1200 feet, indicating that the existing Hoh River valley was once probably filled with glacial deposits.

West of the project area, near the coast, massive and laminated clay deposits have been observed. These deposits suggest stagnation of the Hoh glacier, with the accompanying lake formation in the area occupied by the terminal lobe. This was the last glacier to reach this far west of the Hoh River Valley. Peat bogs north and east of the project area are associated with younger glacial lobes. Alpine glaciers are presently active on the slopes of Mount Olympus (7950 foot elevation); the terminus of the Hoh Glacier was at an elevation of 3940 feet in 1955.

### **Site Geology**

Thick glacial deposits that include lacustrine silts/clays and outwash silty sands and gravels are the dominant soils within the project limits. These deposits, left by the alpine glaciers that originated in the Olympic Mountains during the Pleistocene, include a thick sequence of laminated and massive silts and clays, similar to those identified along the present day coastline at the mouth of the Hoh River. These clays are thought to have been deposited in a glacial lake that formed from the stagnation of the Hoh River glacial lobe. Underlying the lacustrine deposits is a sequence of over-consolidated advanced outwash consisting of silty sands and sandy silts with gravels and glacial tills.

### **Climate And Moisture**

This northwestern Washington site on the Olympic Peninsula receives an average of 119.5 inches of precipitation per year. Snowfall averages 13.6 inches per year falling between December and April with the greatest average depth of 5.6 inches in January. Average maximum temperature is 72.4° F in August and average minimum temperature is 33.5° F in January. Further climate information can be found at:

<http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?wafork>

## **Existing Vegetation**

Existing vegetation on site consisted of a cover of annual rye grass that had been seeded to prevent erosion.

## **Opportunities and Constraints**

This site is part of a much larger road project. The project area had soil conditions that presented different challenges than those of the Chelan and Raymond project sites. For example, heavy marine clay soil on site, naturally dense material, had been further compacted by heavy equipment use during roadway construction.

The Olympic Region Landscape Architect, requested that the Lost Creek site be included in the soil bioengineering research project. The road construction project provided additional funding for roadside work on that site.

This west facing, 180 feet long by 86 feet high slope has ample rainfall. There is a source of willows nearby to aid in constructing the willow walls and brush layers.

The slope had rills and gullies and a shallow rapid landslide with a head scarp near the top of the cut slope. The dense and heavily compacted marine clay presented challenges to all involved, especially the Crews. Prior to the start of the research project, the geological engineer and project manager had placed a rock apron at the base of the slope to counter-weight the slope and to prevent further movement.

Two parallel lines of hay bales had been placed on the slope, approximately along the contours. These had apparently slipped and the resulting downward slope of the bales was channeling surface water to the end of the hay bale row and in addition, water was seeping from between the bales. Exit points of these, concentrated water flows and resulted in small rill and gully formations.

## **Design Solution**

The Lost Creek project was divided into three sub-sites, Site 1, Site 3, and Site 5. Locations of these sites are shown in Figure 9.

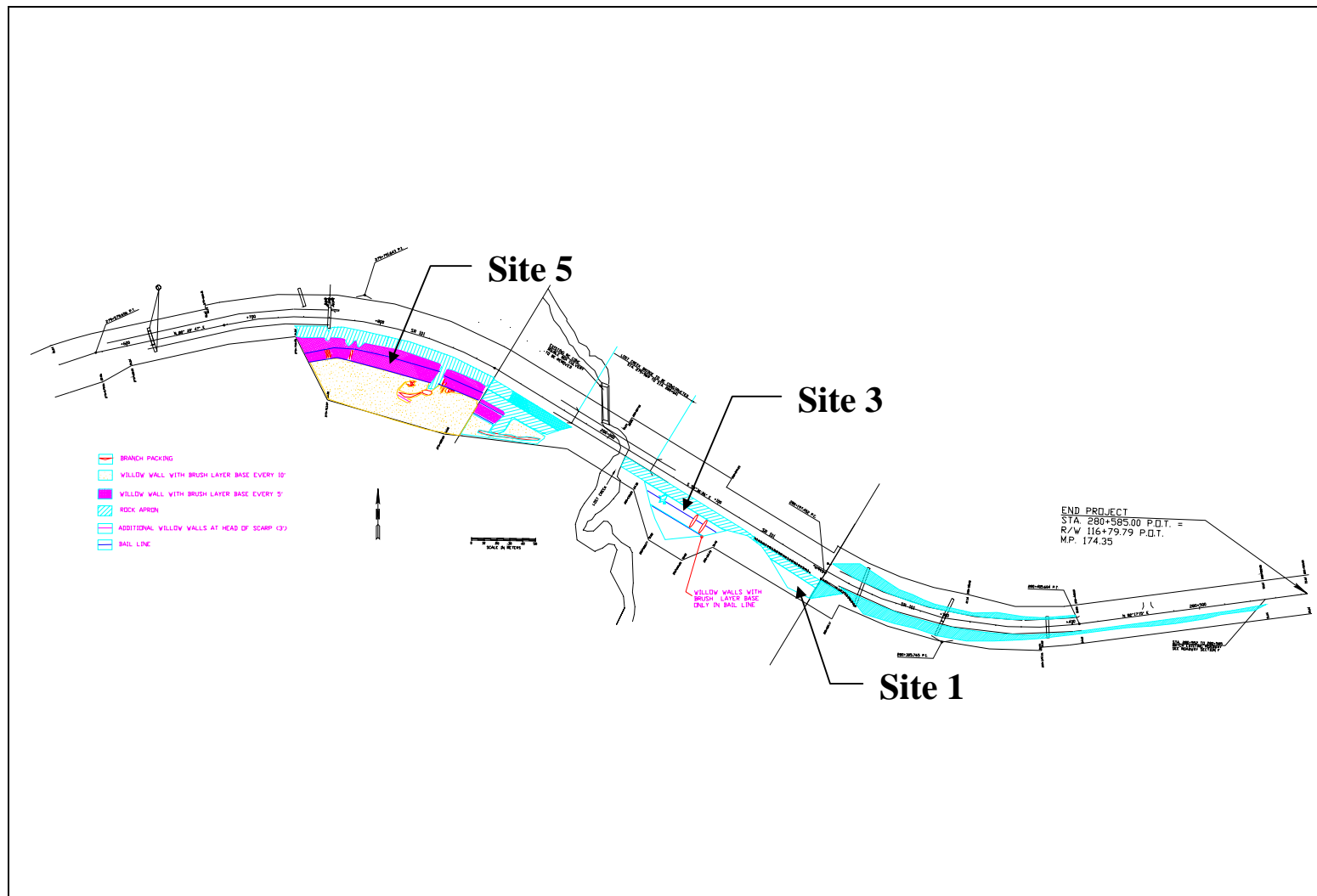
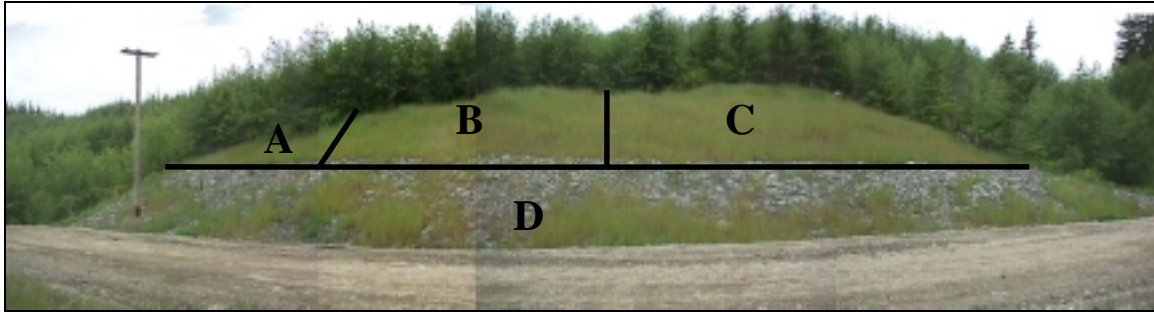


Figure 9. Lost Creek Project Areas

The PI's original design had techniques for all three sites. Her original prescription for Lost Creek follows:

## **Lost Creek Project Objectives**

### **Site 1 (Sections A, B, C, and D)**



**Figure 10. Site 1**

#### **Site 1 - Section A**

Grasses were effective in stabilizing surface erosion. To maintain surface stability and to prevent shallow rapid landsliding:

Plant trees (20%) and shrubs (80%) at minimum of 4 foot x 4 foot spacing.  
Species mix has been selected. RA and WSDOT Landscape Architects will determine placement and spacing.

Benefit:

- With root development, increases soil strength and slope stability

#### **Site 1 - Section B**

Grass minimized surface erosion. To maintain stability and prevent further surface erosion and shallow rapid landsliding:

Create planting "islands" by constructing willow fences.

Dimensions: 10 foot length and 2 foot height or 5 foot to 6 foot length and 2 foot height. Use 3 foot to 4 foot long willows for stakes to support fencing. Follow instructions in attached technical manual. Once constructed, fill behind *willow fence* with soil (preferably a silt loam). Plant shrubs and small trees (i.e. dogwood) within these terraces.

Benefits:

- Reduces slope angle
- Reduces surface erosion (rills and gullies)
- Traps sediments
- Captures and utilizes both surface and subsurface water
- With root development, increases soil strength and slope stability

### **Site 1 - Section C**

Grass minimized surface erosion. Within Site 1, Section C experienced the highest level of surface erosion. This erosion was caused by overland flow and insufficient plant cover and root development. To maintain stability, inhibit additional surface erosion, and prevent shallow rapid landslides:

Create planting “islands” by constructing *willow fence* and *willow fences with a brush layer base*. As noted on the design, locate the *willow fence with a brush layer base* above rocky gullies. Once constructed, fill behind *willow fence with a brush layer base* with soil (preferably a silt loam). Plant shrubs and small trees (i.e. dogwood) within these terraces.

#### Benefits

- Reduces slope angle.
- Reduces surface erosion (rills and gullies).
- Traps sediments.
- Captures and utilizes both surface and subsurface water.
- With root development, increases soil strength and slope stability.
- Slows water movement through sand layer.
- *Willow fence with a brush layer base* provides additional slope protection for critical areas above gullies.

Plant trees and shrubs throughout Sections A, B, and C. Species mix has been selected by PI, RA, and WSDOT Landscape Architects. Location of installation will be determined by RA and Landscape Architect(s) at WSDOT. PI will review to make sure placement meets slope stability objectives.

### **Site 1 - Section D**

To mitigate erosion, a rock apron was placed at base of slope. To complement buttressing effect:

Install live stakes in rock apron. Use stems 1.5 inches to 3 inches in diameter and 2 feet to 3 feet long. Space 2' to 3' apart and tamp into the ground at right angles to the slope. Four-fifths of the stem should be installed into soil. Firm soil around the stem. Trim any splits. If needed, use an iron bar to pilot a hole.

#### Benefit:

- Root systems form a mat which strengthens the soil and removes excess slope moisture.

## LOST CREEK

### Site 3 (Sections A, B, C, and D)

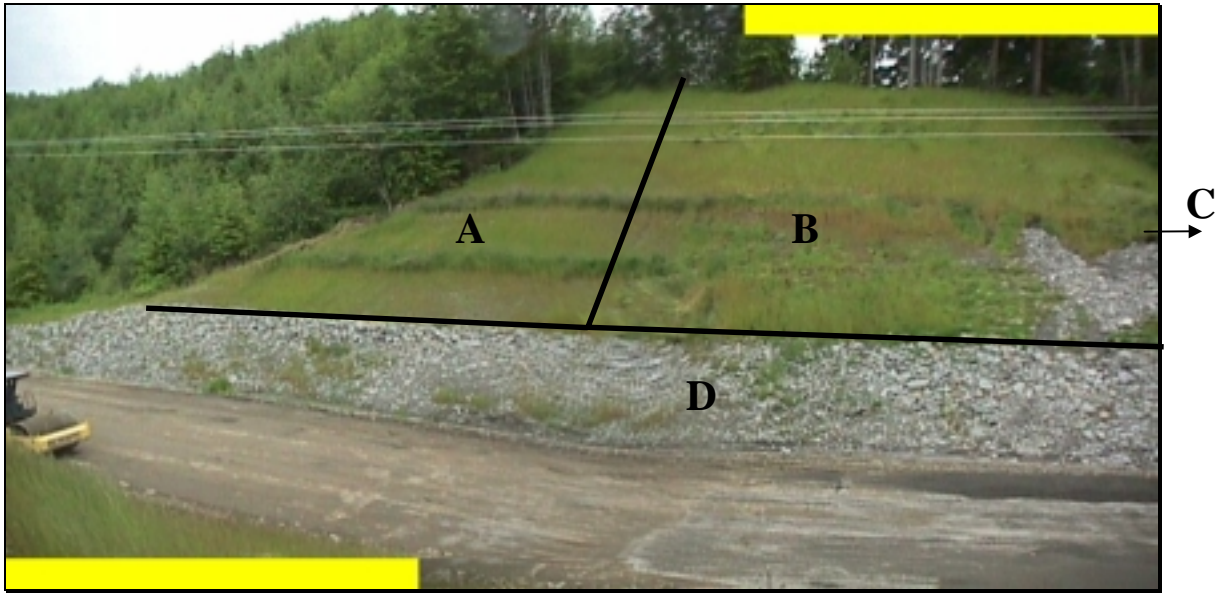


Figure 11. Site 3

#### Site 3 - Section A

Grasses were effective in stabilizing surface erosion. To maintain surface stability and to prevent shallow rapid landsliding:

- Remove all hay bales and rake smooth trapped silts.
- Plant trees (30%) and shrubs (70%) throughout Section A. *Use predominantly (90+%) shrubs in terraced areas behind willow fence.* Plant species have been selected and approved. RA and WSDOT Landscape Architects will determine placement and spacing (minimum 4'x4'). PI will review to make sure placement and spacing meets slope stability objectives.

Benefit:

- With root development, increases soil strength and slope stability.

Starting above rock apron, construct continuous row of *willow fence*.

Dimensions: continuous length and 2 foot height. Use 3 foot to 4 foot long willows for stakes to support fencing. Additional instructions can be found in the soil bioengineering technical manual. Once constructed, fill behind *willow fence* with soil (preferably a silt loam).

Plant shrubs and small trees (i.e. dogwood) within these terraces. RA and WSDOT Landscape Architects will determine placement and spacing (minimum 4'x4'). PI will review to make sure placement and spacing meets slope stability objectives.

Benefits:

- reduces slope angle
- reduces surface erosion (rills and gullies)
- traps sediments
- captures and utilizes both surface and subsurface water
- with root development, increases soil strength and slope stability

### **Site 3 - Section B**

Grasses were effective in stabilizing surface erosion of upper B section. Below this upper section, however, grasses had minimal effect in preventing erosion. Within Site 1, Section C experienced the highest level of surface erosion (rills and gullies). This erosion was caused by overland flow and insufficient plant cover and root development. To maintain stability, inhibit additional surface erosion, and prevent shallow rapid landsliding:

- Remove all hay bales and rake smooth trapped silts.
- In the upper B section, plant trees (40%) and shrubs (60%). Species mix has been selected and approved. RA and WSDOT Landscape Architects will determine placement and spacing (minimum 4'x4'). PI will review to make sure placement and spacing meets slope stability objectives.

Benefit:

- with root development, increases soil strength and slope stability

Starting above rock apron, construct continuous row of *willow fence with a brush layer base*.

Dimensions: continuous length and 2 foot height. Use 3 foot to 4 foot long willows for stakes to support fencing. Four-fifths of length of brush layering willows should be buried within the terrace. Once constructed, trim any excess. *The more stem exposed to air, the more moisture is lost for critical root development.* Additional instructions can be found in the soil bioengineering technical manual. Once constructed, fill behind *willow fence with a brush layer base* and *willow fence* with soil (preferably a silt loam). Plant shrubs and small trees (i.e. dogwood) within these terraces. RA and WSDOT Landscape Architects will determine placement and spacing (minimum 4'x4'). PI will review to make sure placement and spacing meets slope stability objectives. *Note: as noted in the drawing, the upper row has a small section of willow fence.*

Benefits:

- reduces slope angle
- reduces surface erosion (rills and gullies)
- traps sediments
- captures and utilizes both surface and subsurface water
- with root development, increases soil strength and slope stability
- *willow fence with a brush layer base* provides additional slope protection

Construct “live gully repairs” in all gullies, except the one already filled with rock. Use willow stems 1 inch to 2 inch diameter and length determined by depth of gully. Additional instructions can be found in the soil bioengineering technical manual.

Install live stakes in rocked gully. Use stems 1.5 inches to 2.5 inches in diameter and 2 feet to 3 feet long. Space 2' to 3' apart and tamp into the ground at right angles to the slope. Four-fifths of the stem should be installed into soil. Firm soil around the stem. Trim any splits. If needed, use an iron bar to pilot a hole.

Benefit:

- Root systems form a mat which strengthens the soil and removes excess slope moisture.

Plant trees (30%) and shrubs (70%) throughout Section B (excluding rocked gully). *Use predominantly (90+%) shrubs in terraced areas behind willow fence with a brush layer base and willow fence.* Species mix has been selected and approved. RA and WSDOT Landscape Architects will determine placement and spacing (minimum 4'x4'). PI will review to make sure placement and spacing meets slope stability objectives.

### **Site 3 - Section C**

Grasses were effective in stabilizing surface erosion of upper C section. Saturated soils, however, led to small shallow rapid landslide located in center C section. To inhibit area from enlarging and stabilize feature:

Remove all hay bales and rake smooth trapped silts.

Install “branch packing” in shallow rapid landslide. Use willow stems ½ inch to 2 inch diameter. Additional instructions can be found in the soil bioengineering technical manual.

Benefits:

- reconstruction of slope by refilling localized slump
- retards runoff
- reduces surface erosion (rills and gullies)
- captures and utilizes both surface and subsurface water
- with root development, increased soil strength and slope stability

Starting at rock apron, construct continuous rows of *willow fence with a brush layer base*.

Dimensions: continuous length and 2 foot height on both sides of branch packing area. Use 3 foot to 4 foot long willows for stakes to support fencing. Four-fifths of length of brush layering willows should be buried within the terrace. Once constructed, trim any excess. *The more stem exposed to air, the more moisture is lost for critical root development.* Additional instructions can be found in the soil bioengineering technical manual. Once constructed, fill behind *willow fence with a brush layer base and willow fence* with soil (preferably a silt loam). Plant shrubs and small trees (i.e. dogwood) within these terraces. RA and WSDOT Landscape Architects will determine placement



and spacing (minimum 4'x4'). PI will review to make sure placement and spacing meets slope stability objectives. *Note: as noted in the drawing, the upper row is a small section of willow fence.*

Benefits:

- reduces slope angle
- reduces surface erosion (rills and gullies)
- traps sediments
- captures and utilizes both surface and subsurface water
- with root development, increases soil strength and slope stability
- *willow fence with a brush layer base* provides additional slope protection

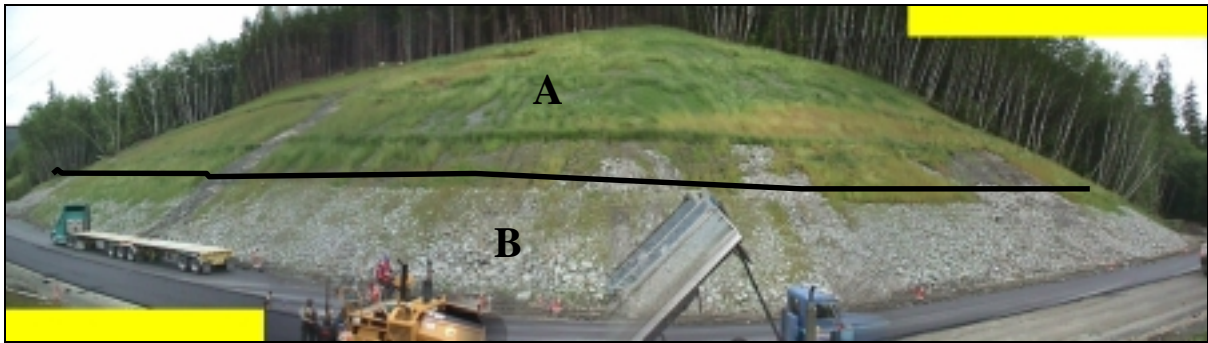
### **Site 3 - Section D**

Install live stakes in rock apron. Use stems 1.5 inches to 3 inches in diameter and 2 feet to 3 feet long. Space 2' to 3' apart and tamp into the ground at right angles to the slope. Four-fifths of the stem should be installed into soil. Firm soil around the stem. Trim any splits. If needed, use an iron bar to pilot a hole.

Benefit:

- Root systems form a mat which strengthens the soil and removes excess slope moisture.

**LOST CREEK**  
**Site 5 (Sections A and B)**



**Figure 12. Site 5 before treatment**

**Site 5 - Section A**

Grass minimized surface erosion. Within Site 5, Section A experienced the highest level of surface erosion. This erosion was caused by high rainfall and subsequent saturated soils. This condition led to excess overland flow and draining hay bales. There was insufficient plant cover and root development to maintain slope stability. To inhibit additional surface erosion and shallow rapid landsliding:

- Remove all hay bales and rake smooth trapped silts.
- Create planting “islands” by constructing (*willow fence with a brush layer base*). Once constructed, fill behind *willow fence with a brush layer base* with soil (preferably a silt loam). Plant shrubs and small trees (i.e. dogwood) within these terraces.

Benefits:

- Reduces slope angle
- Reduces surface erosion (rills and gullies)
- Traps sediments
- Captures and utilizes both surface and subsurface water
- With root development, increases soil strength and slope stability
- Slows water movement through sand layer
- *Willow fence with a brush layer base* provides additional slope protection for critical areas above gullies

Install “branchpacking” in shallow rapid landslide. Use willow stems ½ inch to 2 inch diameter. Additional instructions can be found in the soil bioengineering technical manual.

Benefits:

- Reconstruction of slope by refilling localized slump
- Retards runoff
- Reduces surface erosion (rills and gullies)
- Captures and utilizes both surface and subsurface water
- With root development, increased soil strength and slope stability

Plant trees and shrubs throughout Section A. Species mix has been selected by PI, RA, and WSDOT Landscape Architects. Location of installation will be determined by RA and Landscape Architect(s) at WSDOT. PI will review to make sure placement meets slope stability objectives.

### **Site 5 - Section B**

Install live stakes in rock apron. Use stems 1.5 inches to 3 inches in diameter and 2 feet to 3 feet long. Space 2' to 3' apart and tamp into the ground at right angles to the slope. Four-fifths of the stem should be installed into soil. Firm soil around the stem. Trim any splits. If needed, use an iron bar to pilot a hole.

Benefits:

- Root systems form a mat which strengthens the soil and removes excess slope moisture.

### **Construction**

Construction began on Site 3 on October 25, 1999 with one Crew on willow wall construction. The Crew began using branch packing for one gully according to the original design.

Construction on Site 5 began on November 9, 1999 with the uppermost willow wall. The original intention was to use a winch to bring fill dirt up to the top of the slope. The Crew supervisor had safety concerns with that method and decided hand-carrying buckets of soil up the slope was his preferred method. The Crew had successfully used that method on Site 3 for the previous 2 weeks.

### **Problems and Solutions During Construction**

Construction on the Lost Creek site ran concurrently with construction on the Chelan site. The RA managed her time to be on both sites as much as possible during construction. Members of the research team helped on each site in the RA's absence. However, because of other projects, team members in Olympic Region were not able to be at the Lost Creek site at the same time as the RA to discuss ongoing work, this resulted in some communication problems and caused confusion and conflict with Crew time and work assignments.

Because of the compost contractor's busy schedule, compost was applied to Site 3 before willow walls were constructed, causing erosion problems and slippery footing for the Crew. Without the terraces in place, heavy rains washed some of the compost into the ditch and into Lost Creek.

Sandy, rocky waste soils were delivered to the site, and accepted by the RA instead of the Class C topsoil specified by the PI. The steepness of the slope and the heavy materials that were to be transported up the slope were a source of problems. Various methods of bringing topsoil up this slope were suggested, but none were safe enough with the combination of slick clay, compost, and rain. The Crews had to carry soil and rock up the slope by bucket to fill in gullies and construct the brush layers.

The original plan called for willow wall construction in the same general location as existing hay bales. However, the hay bale rows were not level and encouraged runoff beginning from the center of the hay bale row and extending to the edges of each row. This resulted in erosion of material from behind the hay bales and at each end. After consultation with the PI, the Crew was to begin at the highest point of the hay bale row and continue constructing the willow walls level with that highest point. The RA used a laser level to stake all terraces for the Crews with pink flagging tape as seen in Figure 13. At this point, the RA had to leave for Chelan. While she was gone, the Crew did not follow the RA's instructions and continued to construct the willow wall in the straw bale line. The Crew constructed two additional rows of willow wall that were also not level. The Crew did not understand how to keep the terraces level on a convex surface. For example, Figure 13, below, shows the marking tape where the wall should have been constructed above and behind the stakes the Crew placed.



**Figure 13. Site 3 - Stakes placed below level terrace marking tape**

Due to the amount of surface water received by the gullies on Site 3, the original branch packing design washed out. Additional willow walls were constructed at the head of this gully and the branch packing design was changed to the design seen below.



**Figure 14. Branch packing Parallel to Contours**

Heavier than normal rains, during project construction, led to increased surface and subsurface water movement, resulting in increased surface erosion. Due to water quality concerns, the Hoh Tribe and Washington Department of Fish and Wildlife (WDFW) shut the project down in December until this erosion and sediment runoff could be stopped and additional sediment control measures were installed or improved.

#### **Site 5 dropped from research project**

The Crew supervisor designed a winch system for Site 5. This system was very slow and the amount of time projected to complete the work on Site 5 was out of the scope of the soil bioengineering research project. Because of the size of Site 5 and its complexity and the problems associated with running two projects on the same slope at the same time, Site 5 was dropped from the research project.

Concurrent with this decision, the head scarp on Site 5 began rapidly moving, this rotational failure moved 10-15 feet within a week. A WSDOT geotechnical engineer was brought in, and upon field review, placed this site on WSDOT's list of major erosion sites to be considered for engineering solutions. This confirmed the PI's decision to discontinue soil bioengineering on Site 5.

Construction concluded on Site 3 on January 27, 2000. Native vegetation was planted on Site 3 the week of January 24.

Planted on the Forks site:

<b>Mix A</b>	<b>%Mix</b>	<b># plants</b>
Alnus crispa (Sitka Alder)	3	16.5
Oemleria cerasiformis (Indian-plum)	5	27.5
Mahonia nervosa (Oregon Grape)	6	33
Cornus sericea (Red-osier Dogwood)	14	77
Rubus spectabilis (Salmonberry)	12	66
Amelanchier alnifolia (Serviceberry)	12	66
Salix sitchensis (Sitka Willow)	14	77
Symphoricarpos alba (Snowberry)	12	66
Rubus parviflorus (Thimbleberry)	12	66
Rhamnus purshiana (Cascara)	4	22
Rosa nootkana (Nootka Rose)	4	22
Physocarpus capitatus (Pacific Ninebark)	2	11
<b>Totals</b>	<b>100</b>	<b>550</b>

<b>Mix B</b>	<b>%Mix</b>	<b># plants</b>
Alnus crispa (Sitka Alder)	18	99
Oemleria cerasiformis (Indian-plum)	5	27.5
Mahonia nervosa (Oregon Grape)	5	27.5
Cornus sericea (Red-osier Dogwood)	7	38.5
Rubus spectabilis (Salmonberry)	9	49.5
Amelanchier alnifolia (Serviceberry)	4	22
Salix sitchensis (Sitka Willow)	4	22
Symphoricarpos alba (Snowberry)	23	126.5
Rubus parviflorus (Thimbleberry)	4	22
Rhamnus purshiana (Cascara)	4	22
Rosa nootkana (Nootka Rose)	3	16.5
<b>Totals</b>	<b>86</b>	<b>473</b>

<b>MIX C</b>	<b>%Mix</b>	<b># plants</b>
Thuja plicata (Western Red Cedar)	25	15
Pseudotsuga menziesii (Douglas Fir)	25	15
Tsuga heterophylla (Western Hemlock)	25	15
Picea sitchensis (Sitka Spruce)	25	15
<b>Totals</b>	<b>100</b>	<b>60</b>





**Figure 15. Site 3 Immediately After Construction**

In Figure 16 the top photo shows the site 6 months after construction. The lower photo shows the site prior to construction.



**Figure 16. Site 3 Before and After Soil Bioengineering**

As of July, the head scarp was stabilizing with grasses, shrubs, trees, and willow structures.

## **2000 Monitoring Results**

- Trend is improving to stable
- No evidence of mass movement or gully erosion.
- Site is showing 95% vegetative cover.
- Brushlayer survivability:
  - Brushlayer structures - 80% show new growth.
  - Willow wall structures – 40% show new growth.
- Survivability of vegetation on terraces:
  - Uniform survival above rock apron – 70% overall.
- Uniform survival within the rock apron – 40% overall.